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PAVEMENT RECYCLING USING A HEAVY BULLDOZER MOUNTED PULVERIZER.(U)
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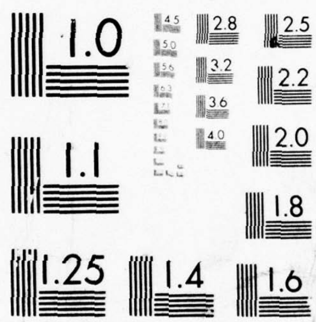

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Special Report 77-30

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PAVEMENT RECYCLING USING A HEAVY BULLDOZER MOUNTED PULVERIZER

Robert A. Eaton
Donald E. Garfield

September 1977

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DIRECTORATE OF MILITARY CONSTRUCTION
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COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Recycling of paving materials is currently gaining acceptance as a means of economic savings in pavement reconstruction or rehabilitation. The need to conserve natural resources and increasing costs of select virgin materials ~~has~~ have made recycling pavements economically attractive. Pavements that currently have low serviceability indices due to surface irregularities such as cracks, bumps, spalling, potholes, etc., may be broken up to meet specified granular base course gradation requirements and reused as a base for the new surface.

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20. Abstract (cont'd) → CRREL
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The U.S. Army Cold Regions Research and Engineering Laboratory developed a permafrost excavating attachment for heavy bulldozers and a prototype test rig was constructed. Tests were conducted on frozen soils, gravels, and ledge. In September 1976, this rig was used to pulverize a flexible street pavement on North Main Street in Hanover, N.H., and highway pavement test sections ~~in~~ at a CRREL test facility. The resultant processed material ~~did meet~~ met Corps of Engineers base course gradation requirements. The machine can process 120 square ft of pavement structure per minute to a depth of 12 inches. The most uniformly graded material was obtained at a drum speed of 15 revolutions per minute. Once the pavement ~~structure~~ is broken down from the solid mass (asphalt concrete pavement), the machine does not further break down or pulverize the aggregate. A minor amount of dust was evident during the operations, but no refinements are recommended as it was an insignificant amount.

Preface

This report was prepared by Robert A. Eaton, Research Civil Engineer, Northern Engineering Research Branch, Experimental Engineering Division, and Donald E. Garfield, Research Mechanical Engineer, Engineering Services Branch, Technical Services Division, U.S. Army Cold Regions Research and Engineering Laboratory.

Funding of this study was provided under the Military Construction DA Project 4K078012AAM1 (O&M) Facilities Investigation and Studies Program; Work Unit 103, Minimize Frost Effects on Pavements.

The authors would like to thank, for their cooperation, assistance, and comments during the conduct of this study, Richard Hauger, Town Engineer, Town of Hanover, New Hampshire; Richard Heath, District Engineer, State of New Hampshire; Frank Aldrich, District Engineer, State of Vermont; personnel of L.M. Pike, Inc., West Lebanon, New Hampshire; and all CRREL personnel involved.

Table of Contents

Introduction

An experimental frozen soil excavation machine was developed and a prototype constructed at CRREL to evaluate a potential method for disaggregating frozen ground for removal by conventional methods and equipment (Appendix B, photos 1 and 2).

Tests in frozen gravel and in rock outcrops showed that the machine and cutting teeth could withstand the most severe cutting conditions that would normally be met.

Recent interest in reuse of pavement aggregate materials and equipment developed to process these materials led to the decision to try the CRREL excavation machine to pulverize pavements in-situ.

A search for possible test pavements was conducted and a street reconstruction project was located in Hanover, NH, approximately one mile from CRREL.

On Monday, 13 September 1976, the CRREL excavation machine was transported on a goose-neck lowbed trailer truck (Appendix B, photo 3) to North Main Street, in Hanover, next to Dartmouth College's Kiewit Computation Center, where it was used to pulverize the pavement and base course.

On Friday, 17 September, the machine was taken inside the Pavements Test Facility at CRREL and used to pulverize the 4-in. asphalt concrete pavement prior to test section reconstruction.

The following report is a description of the performance of the machine on the two projects and recommendations on its future use.

Machine Description

Construction is hampered in many parts of the world because present earthmoving equipment cannot operate effectively in deeply frozen ground, unless costly supplemental methods, such as drilling and blasting, are used to break up the frozen ground. In anticipation of military needs for grading and excavating frozen ground, a method for mechanically disaggregating frozen ground was conceived.

Initial feasibility tests were made with "cold road planers," and design studies were performed. It was decided that a full-scale prototype should be built, which would serve as an experimental test rig rather than a final development. The machine was intended to break up frozen soil for subsequent removal or redistribution with conventional earthmoving equipment. For maximum utilization of present military equipment, the unit was designed as an attachment to a standard military Caterpillar D7-F tractor. This tractor was somewhat smaller than the carrier that was originally intended to be used, but it was the largest military unit available with a torque converter transmission. This latter requirement was levied because of the slow traverse rates and high tractive forces anticipated. In its final configuration, the attachment consists of a hydraulically driven horizontal cutter drum that attaches to bulldozer push arms, together with an auxiliary power source that attaches to the rear of the tractor. Total weight of the complete machine in its present form is approximately 70,000 lb. It is 26 ft. long and is 15.2 ft. wide.

The cutter drum is 12 ft wide and 5 ft in diameter to the tips of the cutters. The cutting picks are heavy duty forged steel, V-face reversible types with tungsten carbide inserts. The picks are arranged on the drum in a herringbone pattern to balance lateral drum forces. Three sets of tracking cutters were used, with a 2-in. lateral spacing between adjacent rings. A tooth clearance angle of 12° was selected, which provided a positive rake angle of 4° for the particular cutting picks used. The lacing pattern called for a total of 219 picks; however, due to physical space limitations five picks had to be omitted. The drum is driven from inside by a pair of two-speed (15-rpm and 30-rpm) radial-piston hydraulic motors (rated maximum power 200-hp). The motors are specially modified for low temperature operation; however, this does not preclude use at high temperatures. The drum mounting can be switched end-for-end on its frame to permit operation in either the climb-milling or up-milling modes with the tractor moving either backward or forward. The drum rotates on a pair of specially designed large-diameter ball bearings. The drum bearings and end mounts are recessed to permit cutting to a drum depth of 40-in.

The auxiliary power unit consists of a 280-hp engine driving a 150 gal/min hydraulic pump at pressures up to 3000 lb/in^2. The pump displacement is manually controlled from the tractor seat. The pump is of the overcenter type to allow continuously variable speed control within either of the two motor speed ranges, and in either direction of drum rotation. The hydraulic circuit is a closed loop system, with several provisions for low temperature operation. A clutch between the engine

and the pump permits unloading the engine during startup and allows intermittent operation of the pump during extremely cold startups. A two-stage oil filtration system with an oversize suction filter was incorporated to prevent pump cavitation. Ball valves were provided to conveniently drain accumulated water from the fuel and oil reservoirs.

Once the auxiliary engine and pump are started, all controls are manipulated by the tractor operator. The tractor controls, including the dozer lift and tilt controls, are utilized. Additional controls include the variable drum speed/direction control, the drum speed-range lever, and an emergency engine shut-off switch. Instrumentation includes a tachometer for the auxiliary engine and system pressure gages. With the information from these gages, drum speed measurements, and the manufacturers' information on pump and motor characteristics, drum power can be calculated.

Tests in frozen gravel and in rock outcrops have demonstrated that the machine and its cutting teeth could withstand the most severe cutting conditions that would normally be met. In frozen gravel, cutting rates at a drum operating depth of 1-ft averaged 1.5 ft/min at 30-rpm drum speed and 1.7 ft/min at 15-rpm. Operating at the same depth in frozen silt, cutting rates averaged 1.8 ft/min at both 30-rpm and 15-rpm drum speeds; however, cutting rates varied considerably at the lower drum speed. Allowing for hydraulic and mechanical losses, net drum power available for cutting was 130 hp at 30 rpm and 150 hp at 15 rpm. Based on operating at a depth of 1-ft, low "power densities" (power per unit area of cutting surface) of 4.67 hp/ft^2 at 30-rpm and 5.39 hp/ft^2 at

15-rpm were realized with this machine. The "process specific energy" (energy required per unit volume of material removed) averaged 1670 in.-lb/in.^{3} in frozen gravel and 1485 in. lb/in.^{3} in frozen silt.

Field Tests

North Main Street, Hanover, N.H.

At the test site on North Main Street the Town was undercutting the street approximately 24 in. for reconstruction. Samples of the granular base course and black base beneath the 4-5 in. asphalt concrete pavement were obtained. The machine was moved up to the edge of the 24 in. vertical cut with the drum horizontally overhanging approximately 12 in. The drum was operated in the climb milling mode with the tractor in reverse gear, which means the pavement cuttings were forced down into the base material before being discharged at the front of the machine. The drum speed was 15 rpm and set at a depth of 6 in. The machine was backed down the street an average speed of 10 ft/min, resulting in an area of 120 square feet of pulverized pavement six inches deep in one minute. The pavement was pulverized to a relatively uniform gradation (Appendix B, photo 4).

The drum speed was increased to 30 rpm at the same 6 in. operating depth, and backed down the street at the same average speed of 10 ft per minute. The pavement broke off in larger pieces (about 6 in. maximum size). This was mainly caused by low drum torque and frequent stalling of the drum, resulting in erratic traverse speeds.

The drum was next lowered to a depth of 9-12 in. at 15 rpm and 10 ft/min speed and the resulting combination pulverized pavement/basecourse

material was relatively uniform in gradation (Appendix B, photo 5). When the rpm was increased to 30 at the same 9-12-in. depth and same traverse speed, larger pieces were again in evidence. At one point the drum was lowered to a depth of 22 in. below the pavement surface (Appendix B, photo 6). The traverse speed was slower, but the machine had no problems other than stalling the drum when boulders were encountered. There was some carryover or material passing over the top of the drum at the 22-in. depth, but no buildup of material behind the drum was evident.

Other tests were conducted at varying drum rpm, depth, and second passes, until a hydraulic line burst and fluid was lost on the street.

ATCO BUILDING

The machine was returned to CRREL and the hydraulic line was repaired.

On Friday, 17 September 1976, the machine was taken inside the CRREL highway pavements test facility, a 130 ft x 40 ft structure, within which controlled freezing tests are conducted upon various pavement test sections.

The sections were to be reconstructed and the machine was used to pulverize the 4-in. thick asphalt concrete pavement.

The testing sequence was similar to that used on North Main Street. With the drum speed set at 15 rpm at a 4-in. depth, a traverse speed of 9 ft/min was maintained. At 30 rpm at a 4-in. depth, a speed of 8 ft/min was maintained with larger pieces of pavement in evidence.

Other tests conducted were:

30 rpm	19-in. depth	3.5 ft/min
15 rpm	16-in. depth	8 ft/min
30 rpm	8-in. depth	6 ft/min
30 rpm	8-in. depth	20 ft/min over test area above.

Upon completion of the flexible pavement pulverization, a 10 ft square slab of unreinforced concrete 8 in. thick, that had been used as an equipment pad, was pulverized.

Test Results

The Corps of Engineers Guide Specification for Graded-Crushed Aggate for Base Course was used to analyze the pulverized pavement gradation. The gradation is shown in the following table:

TABLE I: Corps of Engineers Specification for Graded-Crushed Aggregate Base Course*

Sieve	% Passing #1	#2	#3
2"	100		-
1-1/2"	70-100	100	-
1"	45-80	60-100	100
1/2"	30-60	30-65	40-70
#4	20-50	20-50	20-50
#10	15-40	15-40	15-40
#40	5-25	5-25	5-25
#200	0-10	0-10	0-10

* NOTE: From Corps of Engineers Guide Specification CE 870.07, Oct. 1972, Grade-Crushed Aggregate Base Courses, Table I.

Gradation #1 is used for this analysis.

On North Main Street, samples of the 2-in. layer of black base course immediately below the 4 in. asphalt concrete pavement, and the 18-in. layer of granular base course were obtained prior to operation of the machine. Gradations are shown in Appendix A. The black base gradation on graph A-1 shows that the material is fine with material above the Corps of

Engineers spec limits from the 1 in. to the #10 sieves. Conversely, the granular base course gradation on the A-2 graph shows that the material is coarser than the Corps specs from the 3 in. to #10 sieve.

These facts should be kept in mind for the following analysis as the fine black base lift is only 2 in. thick whereas the coarser base course material is approximately 18 in. thick.

On the first pass of the machine at a depth of 6 in. (4 in. pavement and 2 in. black base) the pulverized mixture gradation shown in graph A-3 indica s a material coarser than the Corps spec limits. This shows that the rser pavement gradation dominates the finer black base gradation. On the second pass over the same material however, graph A-4, the mixture is blended with more of the fine black base in evidence. The gradation from the 2 in. to 3/4 in. sieve falls within the Corps spec and it is finer than the 1st pass from the 3/4 in. to #10 sieve. However, it is still slightly below the lower limit of the specifications.

On the first pass at the 12 in. depth (4 in. pavement, 2 in. black base, 6 in. granular base course) graph A-5, the coarser pavement gradation dominates the sampled mixture as shown by the curve which is below the lower spec limit. The second pass over the same mixture however, shows better blending of the finer black base and granular material with the resulting gradation falling within the Corps of Engineers specs for crushed aggregate base course, graph A-6. Due to a testing oversight, no gradations under the #10 sieve are available.

Inside the ATCO building, with samples obtained from the 4 in. pulverized asphalt concrete only (no base was mixed with the pavement) the first pass, graph A-7 shows the mixture falling within Corps of

Engineers specs from the 2 in. to #4 sieve with material on the #10 and #20 sieve coarser, and below specs. The second pass over the same material resulted in a gradation, graph A-8, with essentially the same percentages passing as the first pass. Table A-1 shows the gradation of the pavement constructed in the ATCO building. This shows that the CRREL pulverizer machine does not continue to break down the material once it is disaggregated from the solid mass (breaking up of pavement). Figure A-9 proves this with the gradation of the asphalt pavement base and surface courses to the right or finer than the pulverized material.

The machine appeared to perform better in asphalt than in frozen ground. Considering a 4 in. operating depth and average traverse rates of 9 ft/min, specific energies of 954 in.-lb/in^3 and 828 in.-lb/in^3 were calculated for drum speeds of 15 rpm and 30 rpm, respectively. The improved performance in the asphalt vs. frozen ground may be the result of the shallower operating depths in asphalt, resulting in power densities almost twice as great as when operating in frozen ground. Power densities in the asphalt were found to be 9.57 hp/ft^2 at 15 rpm and 8.30 hp/ft^2 at 30 rpm drum speeds.

Conclusions

The CRREL-developed excavation machine was successfully used to pulverize pavements and pavement structures in two locations.

The resulting material did meet Corps of Engineers Guide Specifications for Graded-Crushed Aggregate for Base Course when passed over a second time in an area pulverized to a depth of 12 in.where the pavement, black base, and granular base course were mixed.

The machine can process 120 square feet of pavement structure per minute to a depth of 9-12 in.

At 15 revolutions per minute drum speed the most uniformly graded material is obtained.

Once the pavement structure is broken down from the solid mass (asphalt concrete pavement), the machine does not further break down or pulverize the aggregate.

Recommendations

Larger pieces of pavement were broken off at the higher drum speed of 30 rpm due to erratic traverse speeds caused by low drum torque and resultant stalling. A means of continuous traverse speed control is required to eliminate the jerking movement which causes drum stalling.

A method of maintaining constant depth control on the drum and counterweights on the rear is required to assure uniformity of depth in the processed material. Because the center of gravity of the machine is so far forward, maintaining a constant drum depth is difficult, particularly when operating on uneven pavement surfaces.

The CMI Corporation developed Roto-mill which is currently on the market and in use, does everything we were planning on doing to this rig. It is recommended that field recycling projects where the Roto-mill or other similar machines are to be used, be located and monitored.

Research on recycled pavements is now required to analyze their freeze-thaw performance and develop frost design criteria for the Corps.

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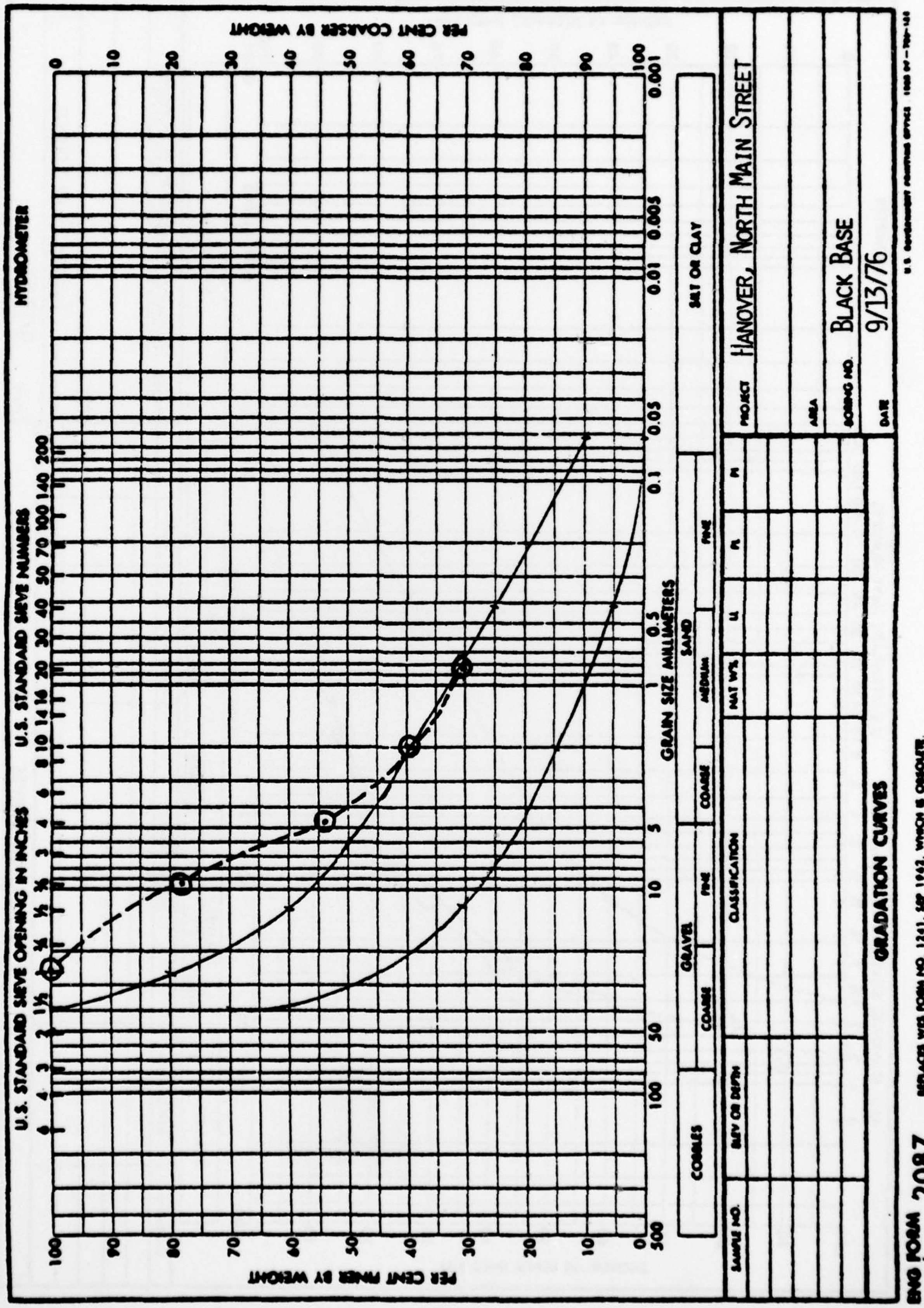
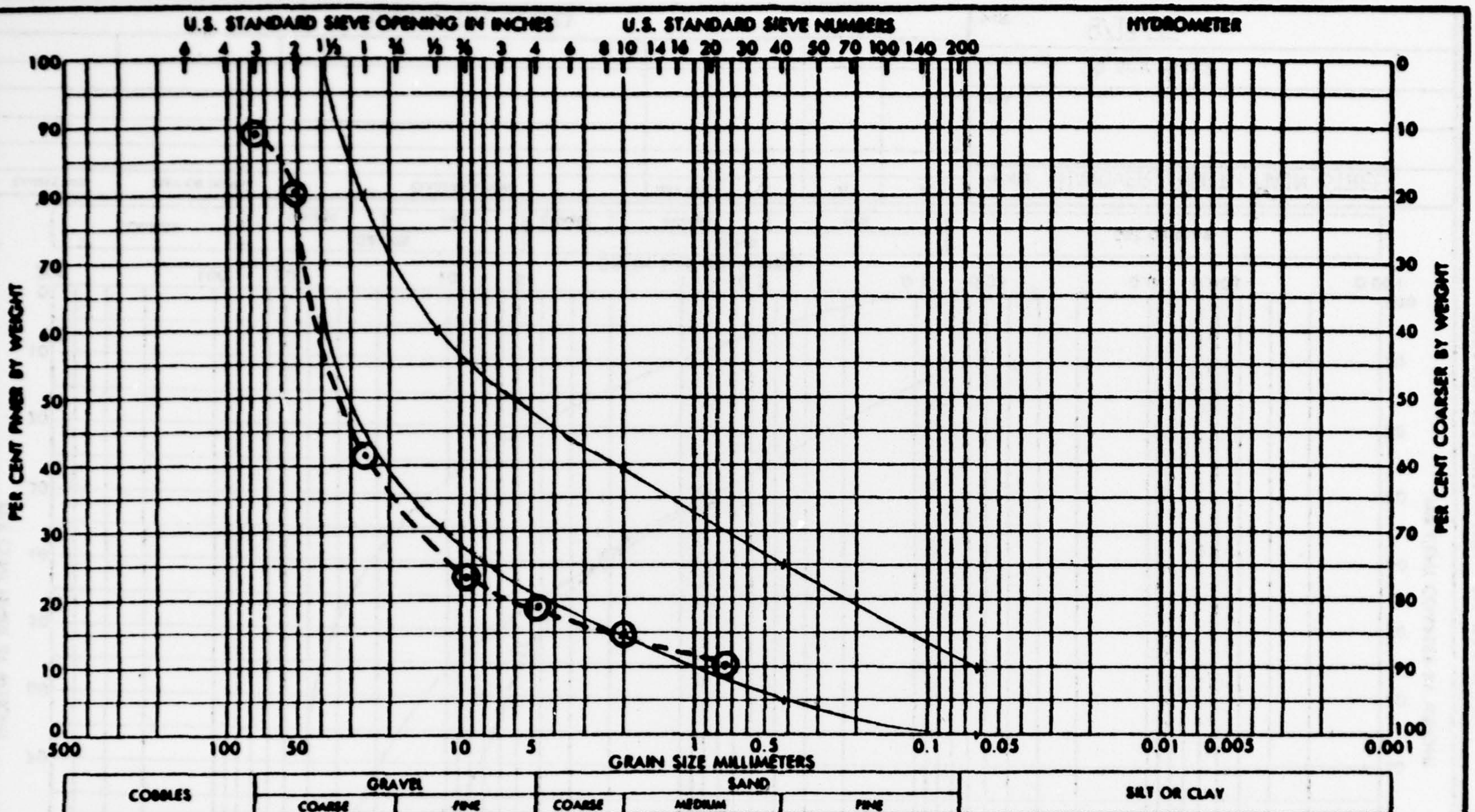
APPENDIX A: MATERIAL GRADATIONS





SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

GRADATION CURVES

PROJECT HANOVER, NORTH MAIN STREET

AREA

BORING NO. GRAVEL BASE COURSE

DATE 9/13/76

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1 MAY 63

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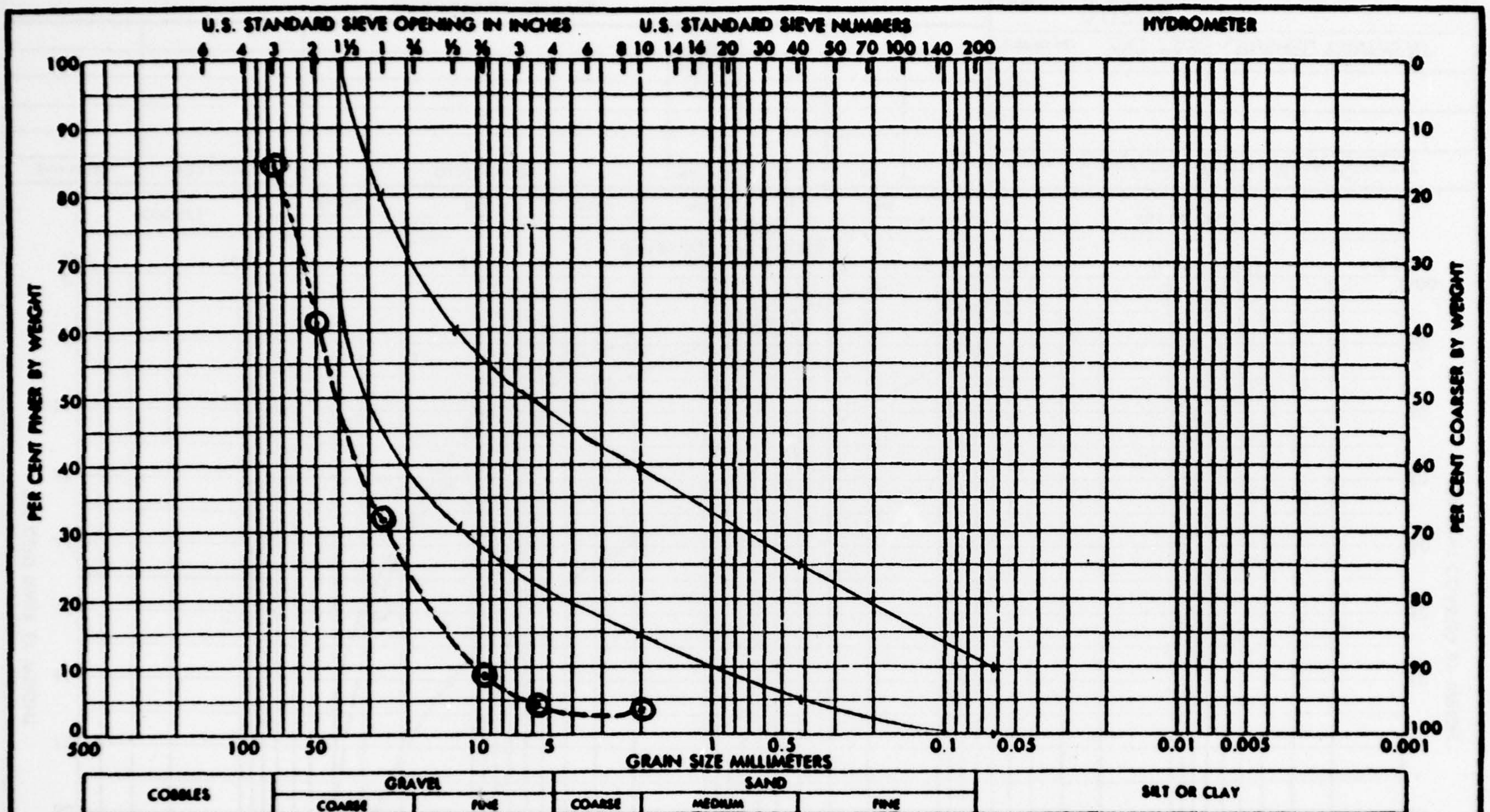

SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

PROJECT HANOVER, NORTH MAIN STREET

AREA

BORING NO. 1ST PASS CRUSHED PAVEMENT

DATE 9/13/76

GRADATION CURVES

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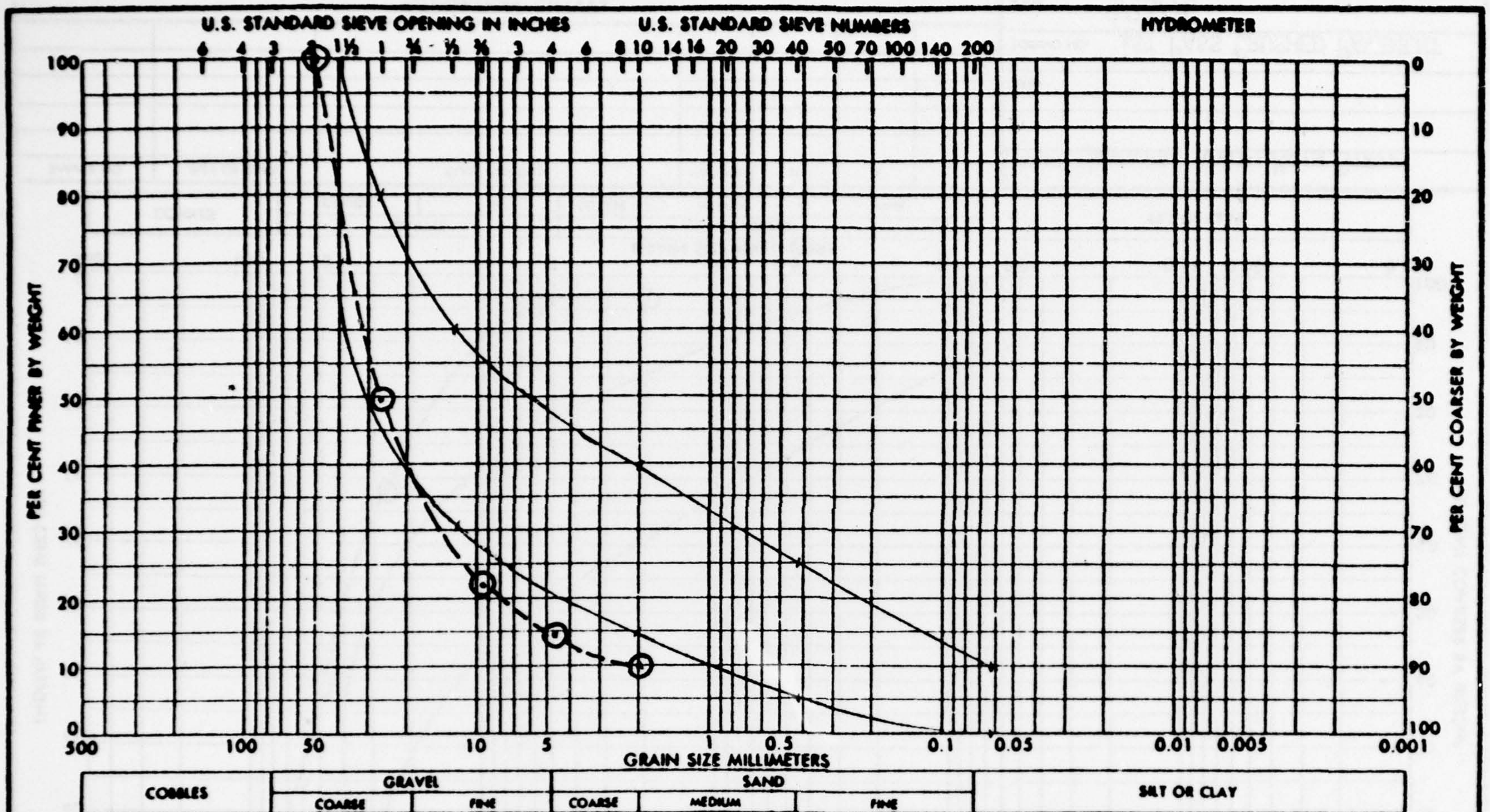

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PROJECT HANOVER, NORTH MAIN STREET

AREA

BORING NO. 2ND PASS CRUSHED PAVEMENT

DATE 9/13/76

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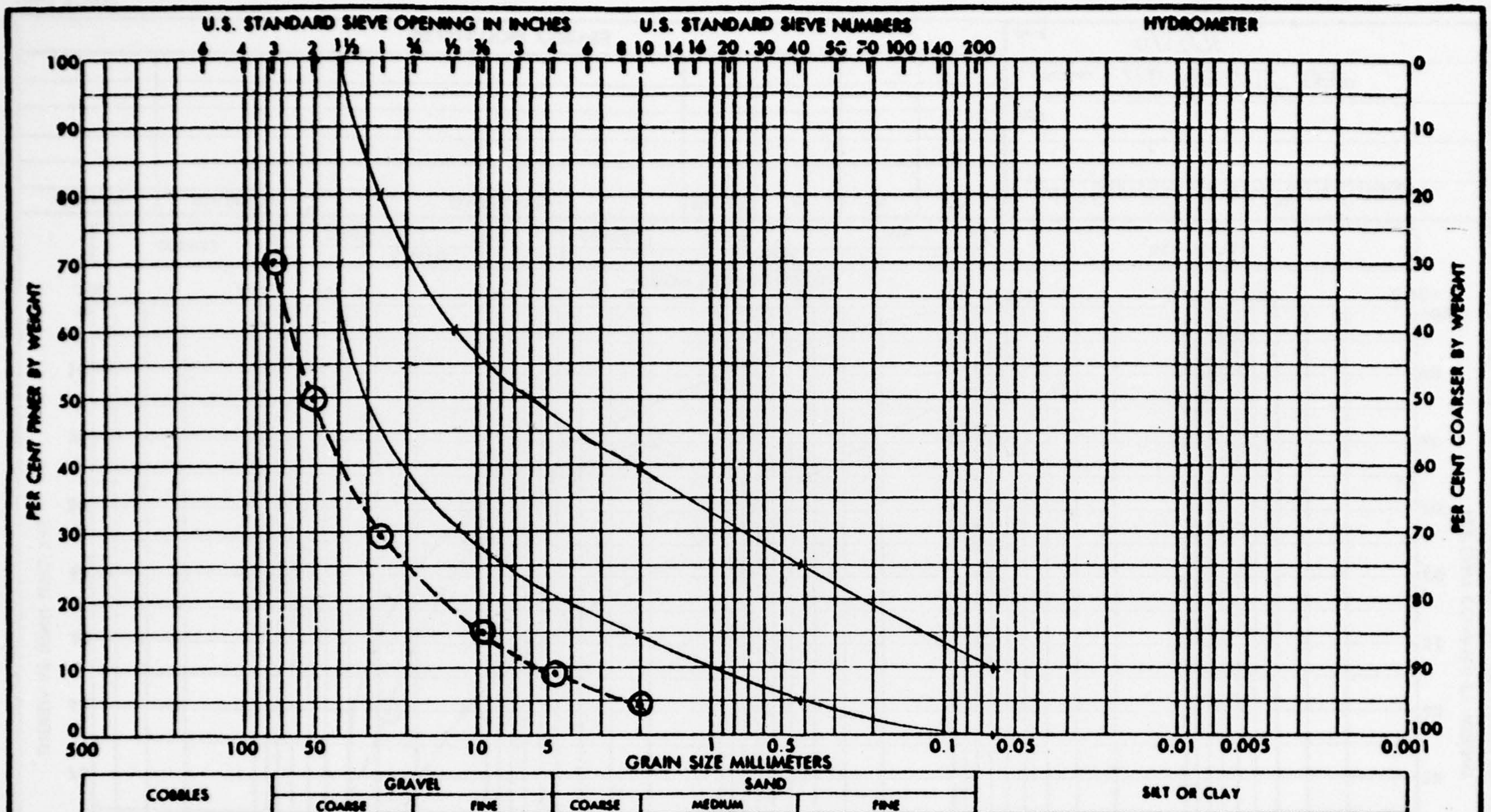

SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

PROJECT HANOVER, NORTH MAIN STREET

AREA

BORING NO. 1ST PASS 12" DEEP

DATE 9/13/76

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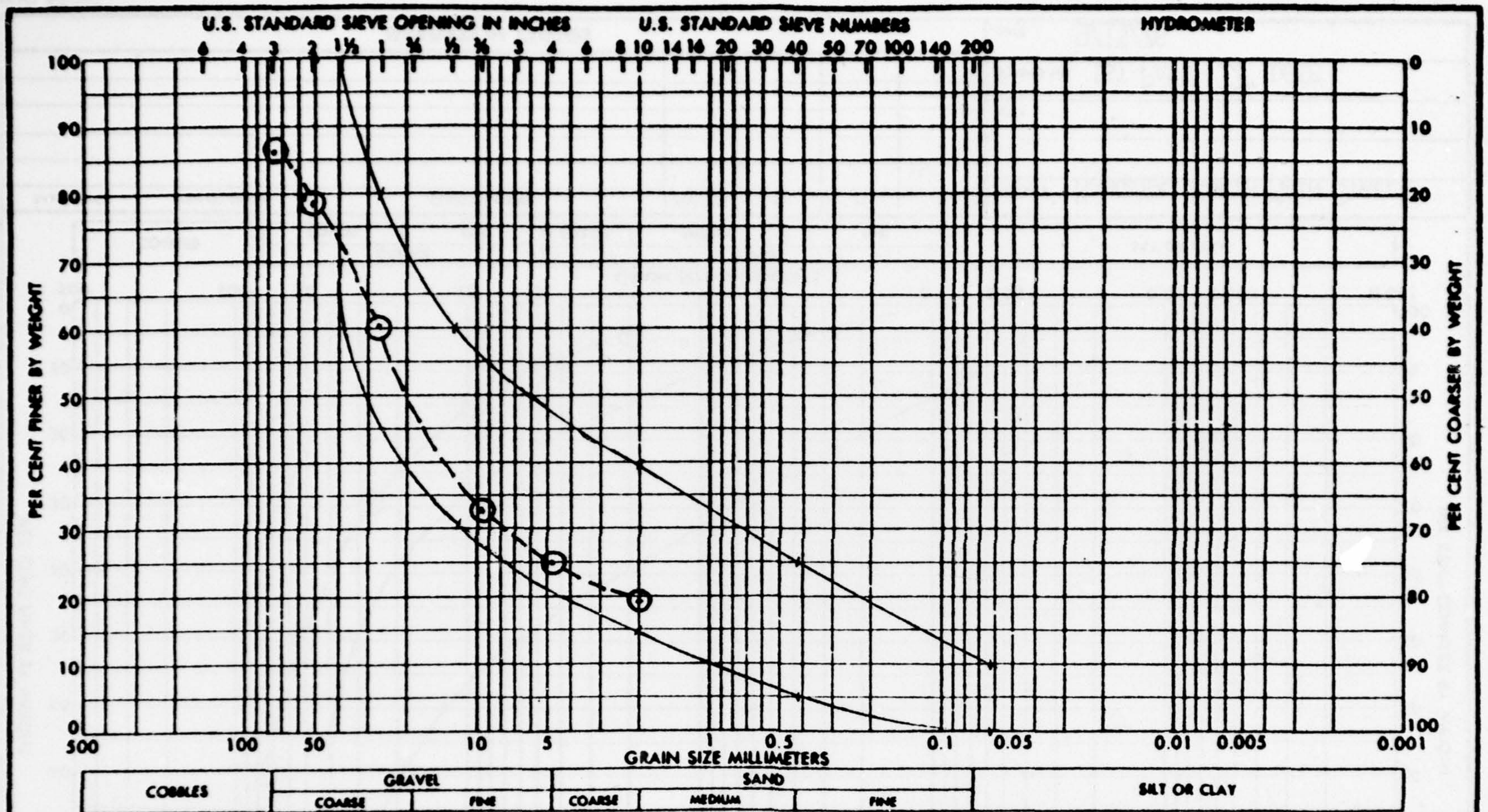

SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

PROJECT Hanover, North Main Street

AREA

BORING NO 2nd Pass 12" deep

DATE 9/13/76

GRADATION CURVES

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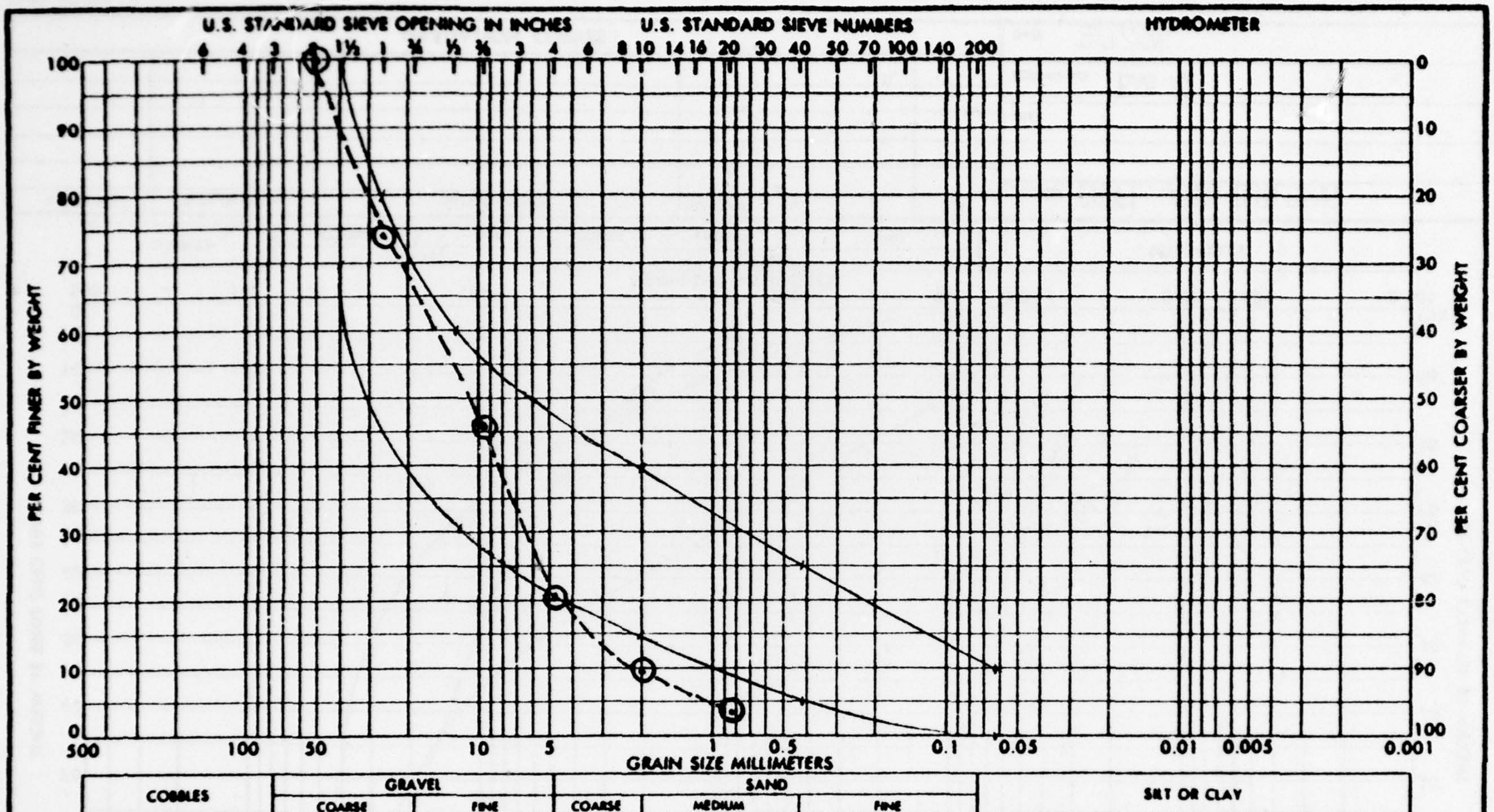

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PROJECT CRREL, ATCO BUILDING

AREA

BORING NO. BAG #1

DATE 9/17/76

GRADATION CURVES

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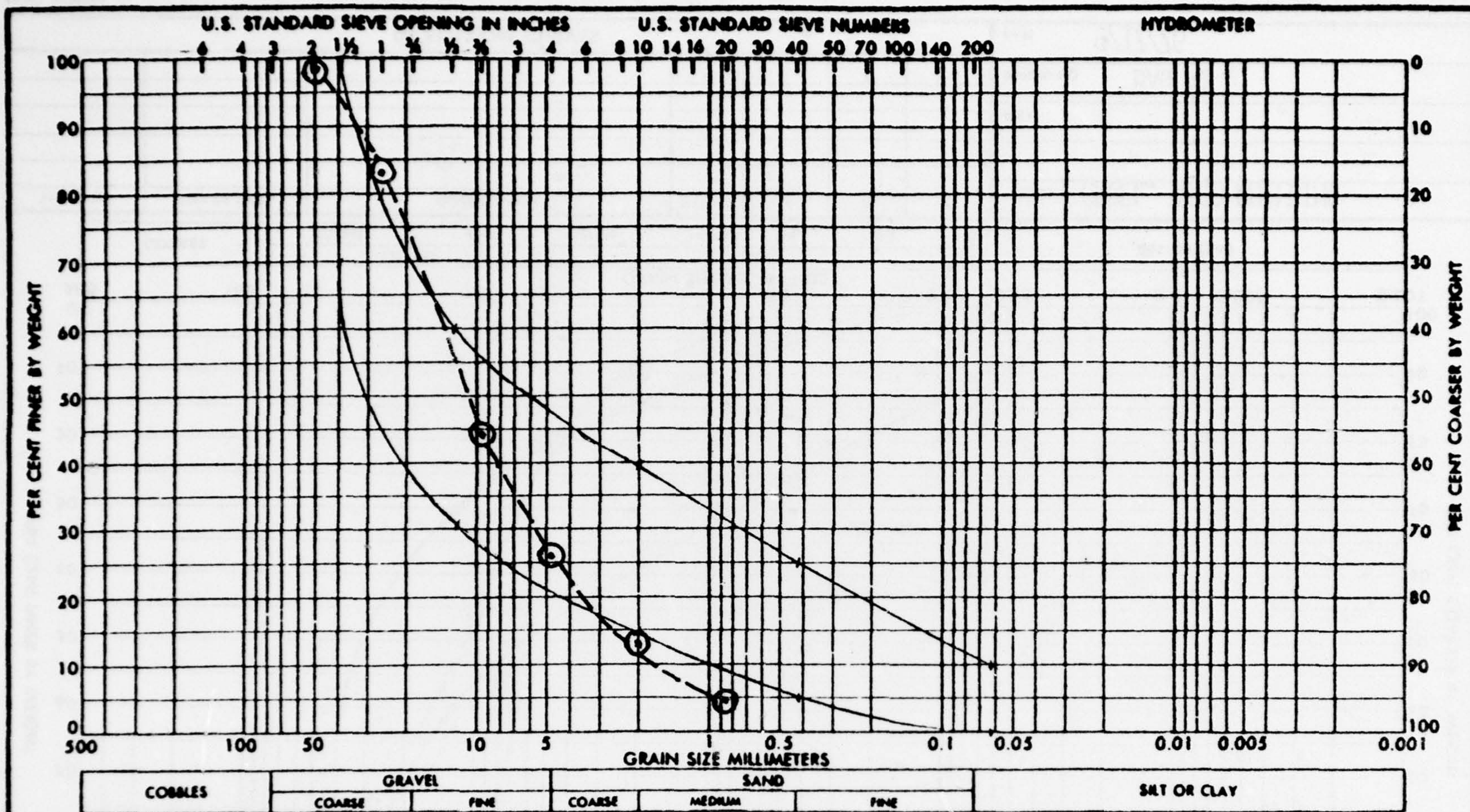

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							AREA
							BORING NO. BAG #2
GRADATION CURVES							DATE 9/17/76

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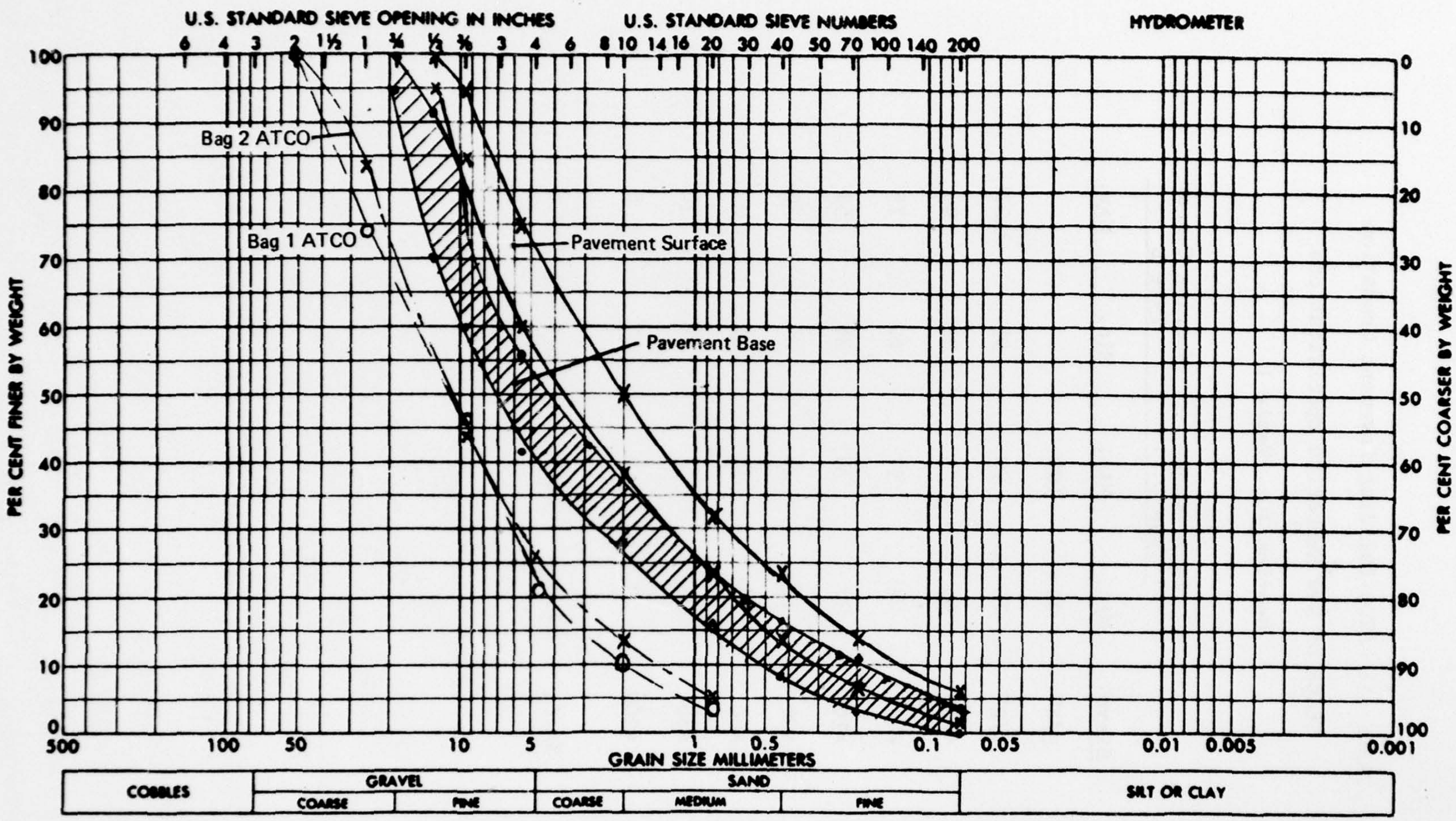

CRREL, AICO Building, 19 Sep 1976.

TABLE A1: ATCO Building Pavement Gradation

State of New Hampshire Specifications

Section 401, Table 1

	Base Course Type C		Wearing Course Type D	
Sieve	Min.	Min.	Min.	Max.
3/4"	95	100	-	-
1/2"	70	92	95	100
3/8"	60	80	85	95
#4	42	57	60	75
#10	28	38	38	50
#20	16	24	24	32
#40	9	17	14	23
#80	3	11	6	14
#200	0	4	2	6
%A.C.	4.8	6.0	6.0	7.0

APPENDIX B: PHOTOS OF EQUIPMENT

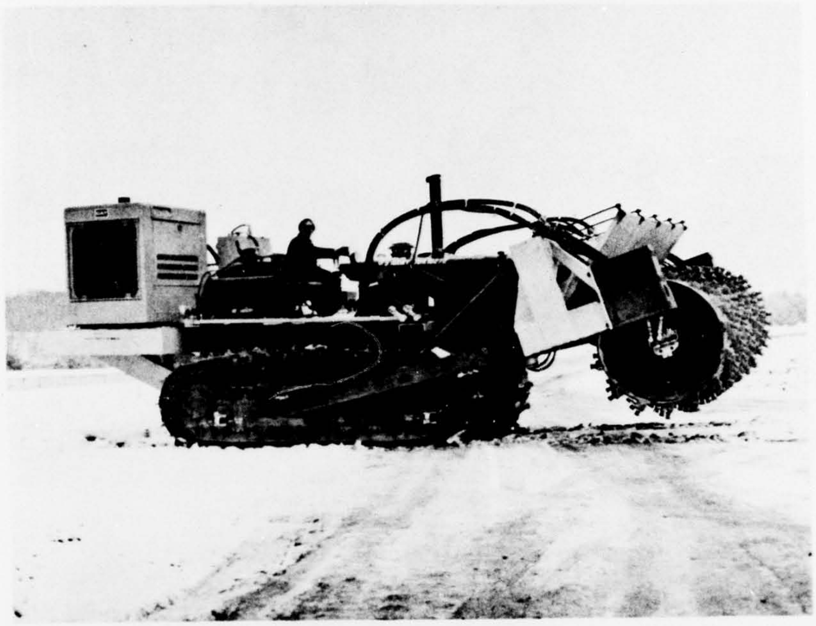

Photo 1: Side View of Test Rig

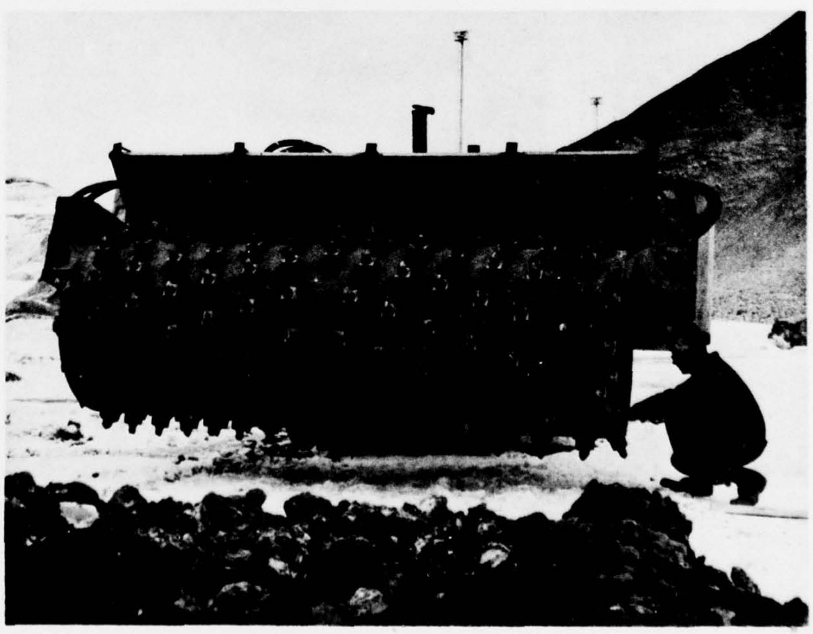

Photo 2: Front View Showing Drum and Teeth

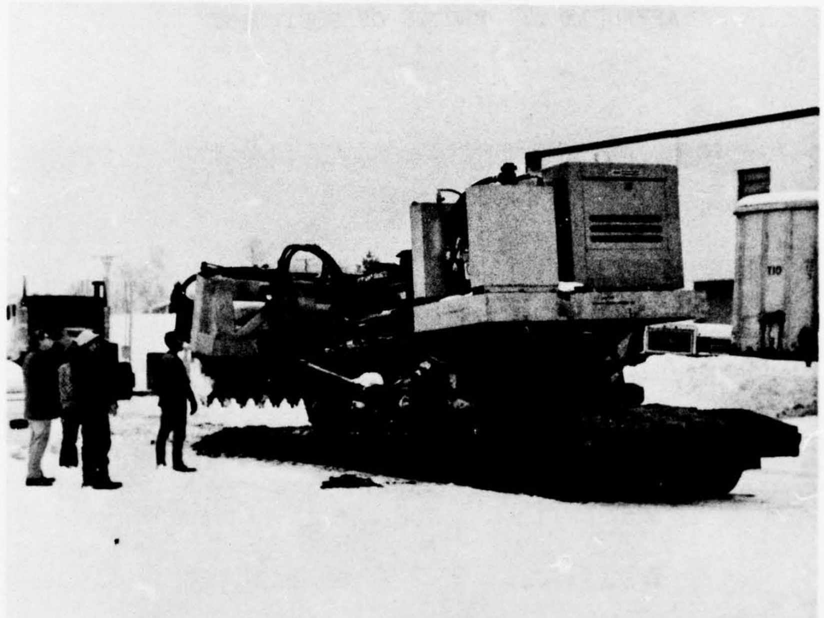

Photo 3: Rig Loaded For Transport

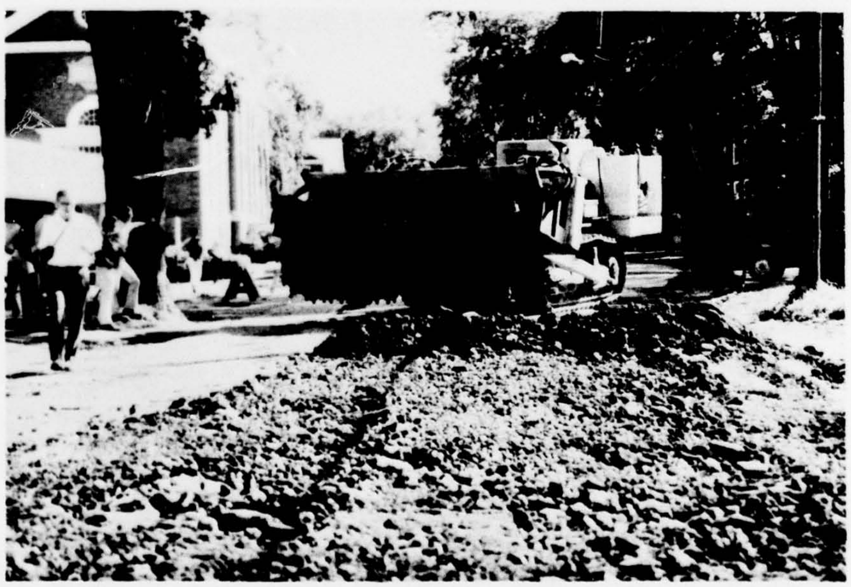

Photo 4: First pass on North Main Street, Hanover, New Hampshire.

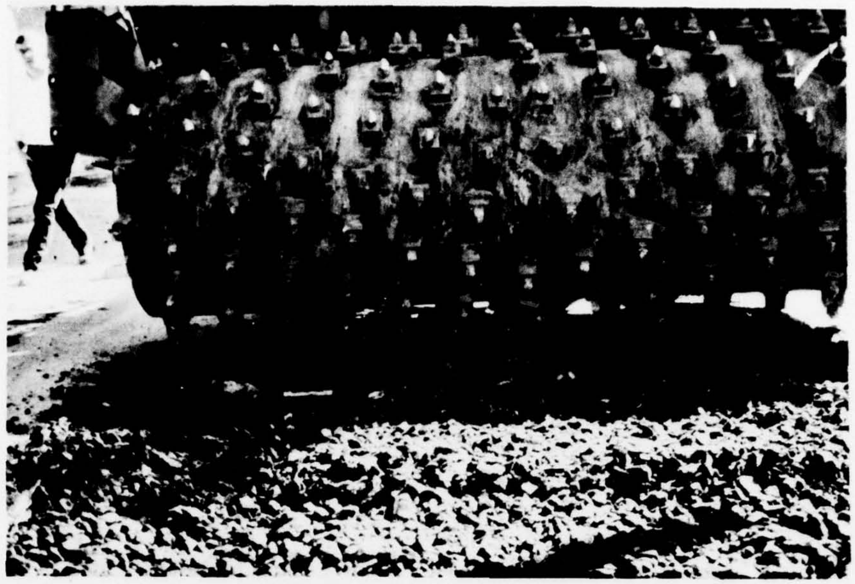

Photo 5. Closeup of pulverized pavement.

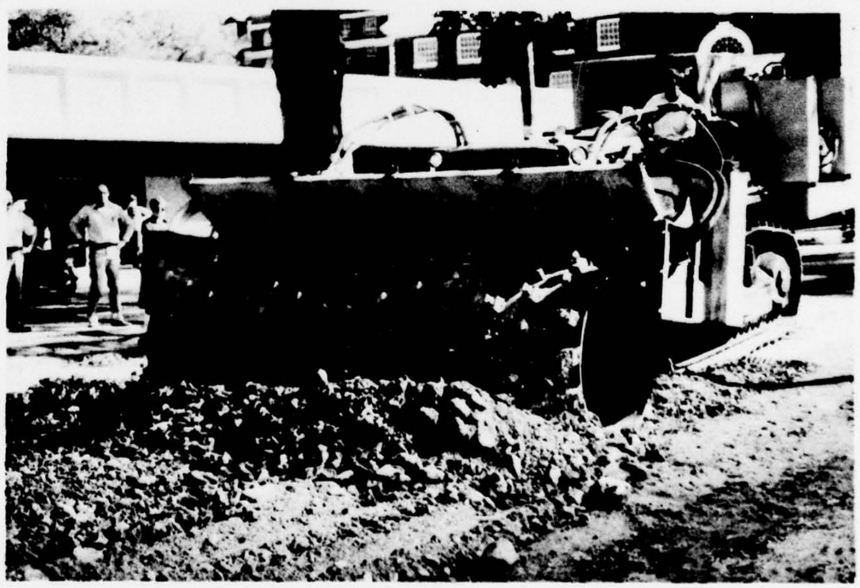

Photo 6: Drum lowered to 22 in.